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Throughfall exclusion and fertilization effects on soil CO₂ efflux at a loblolly pine plantation in Georgia

Introduction

- A major goal of the Pine Integrated Network: Education, Mitigation and Adaptation Project (PINEMAP) is to increase carbon (C) sequestration in planted southern pine forests.
- Storage of C in the soil depends on the rate of litter inputs and the rate of decay of existing C pools.
- Soil carbon dioxide (CO₂) efflux (often referred to as soil respiration, R_s) can be partitioned into autotrophic and heterotrophic components (Figure 1) to establish the amount of gross primary productivity allocated to roots and the rate of decay of old soil C.
- Understanding how trees alter their allocation of C to storage - particularly underground in the roots - in response to water and/or nutrient stress is also useful for predicting soil C storage.
- We are addressing two research questions at a young loblolly pine plantation in Washington, Georgia (a tier III throughfall exclusion and fertilization manipulation site).
- First, how is R_s affected by throughfall exclusion and fertilization treatments?**
- Second, what are the relative contributions of heterotrophic and autotrophic respiration to R_s?**
- These questions are being approached at four tier III sites within the natural range of loblolly pine.

Methods

- Our first aim is to characterize the effect of rainfall and nutrients on R_s.
- This is accomplished using 30% throughfall exclusion and optimal fertilization treatments in a 2 × 2 factorial design, with 4 replicates per factorial (Figure 2).
- The effect of inherent variation among the trees is minimized using blocking (Figure 2).
- Total R_s is measured using a Licor LI-6400 Portable Photosynthesis System with a soil chamber attachment (Figure 3).
- Soil volumetric water content (VWC) and temperature (T_s) were measured with each R_s measurement.
- Measurements are taken approximately every 8 weeks in the colder months and every 4 weeks during the warmer months.
- Data were averaged across plot position to extrapolate responses to the whole plot level and averaged by plot and date of measurement.
- Fertilization and rainfall exclusion effects were tested using a two factor repeated measures analysis of variance (Proc Mixed, SAS Inc., Cary, NC) with the covariance structure for each variable determined using corrected Akaike criteria (AICC).
- Main or interactive effects were considered significant at the α = 0.10 level.
- Analyses were performed on log transformed data when needed to satisfy heterogeneity of variance assumptions.
- Our second aim is to quantify the heterotrophic and autotrophic components of R_s.
- Root exclusion cores are currently being installed for the purpose of cutting off the influx of carbohydrates from parent trees to roots.
- R_s measured above these cores will comprise the heterotrophic respiration component.
- Subtraction from total R_s will yield the autotrophic respiration component.

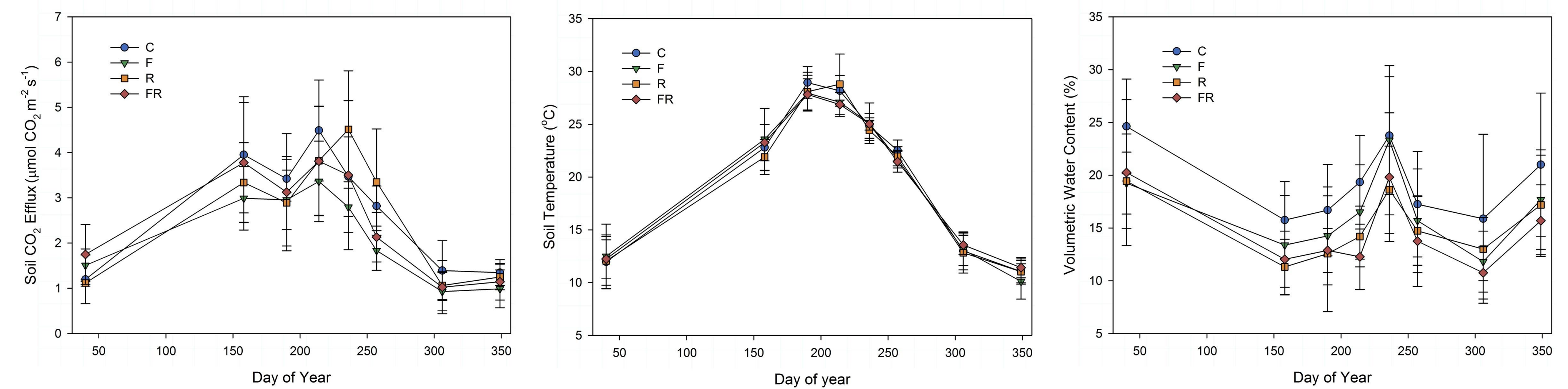


Figure 4: The effects of control (C), fertilization (F), throughfall exclusion (R), and fertilization and throughfall exclusion (FR) on soil CO₂ efflux, soil temperature, and soil volumetric water content over time.

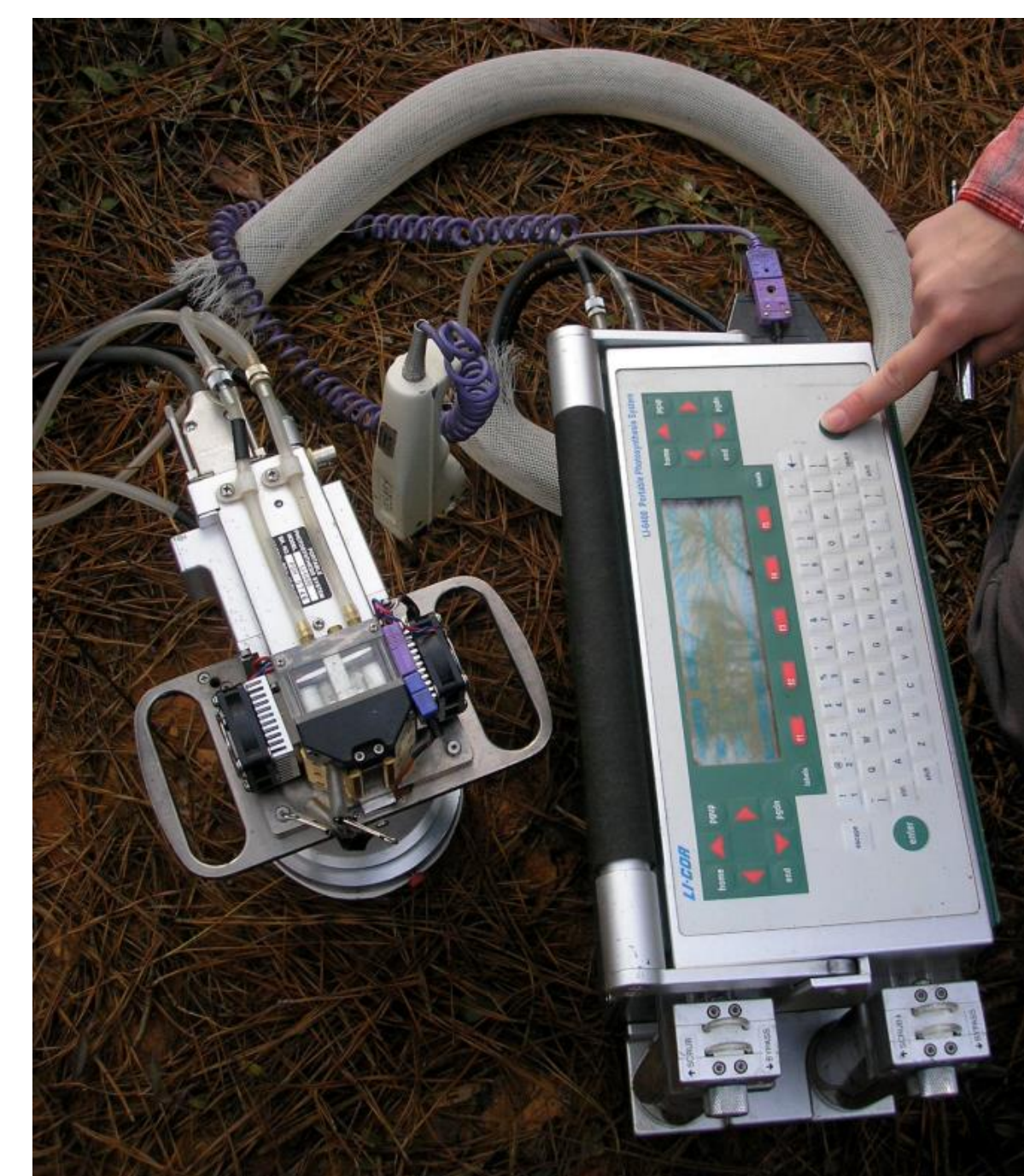


Figure 3: Li-6400 Portable Photosynthesis System with soil chamber attachment.

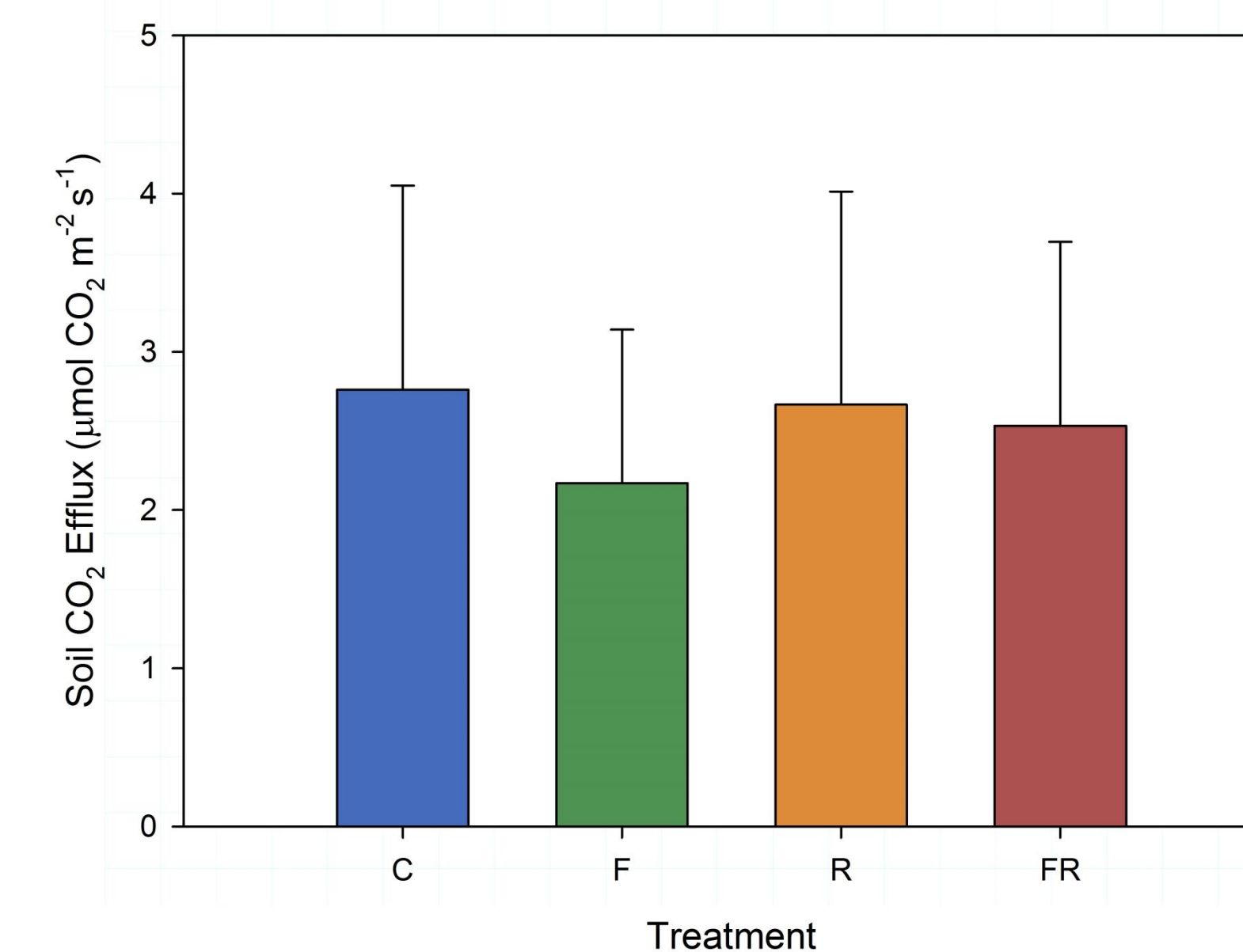


Figure 4: Annual mean soil CO₂ efflux rates by treatment: control (C), fertilization (F), throughfall exclusion (R), and fertilization and throughfall exclusion (FR).

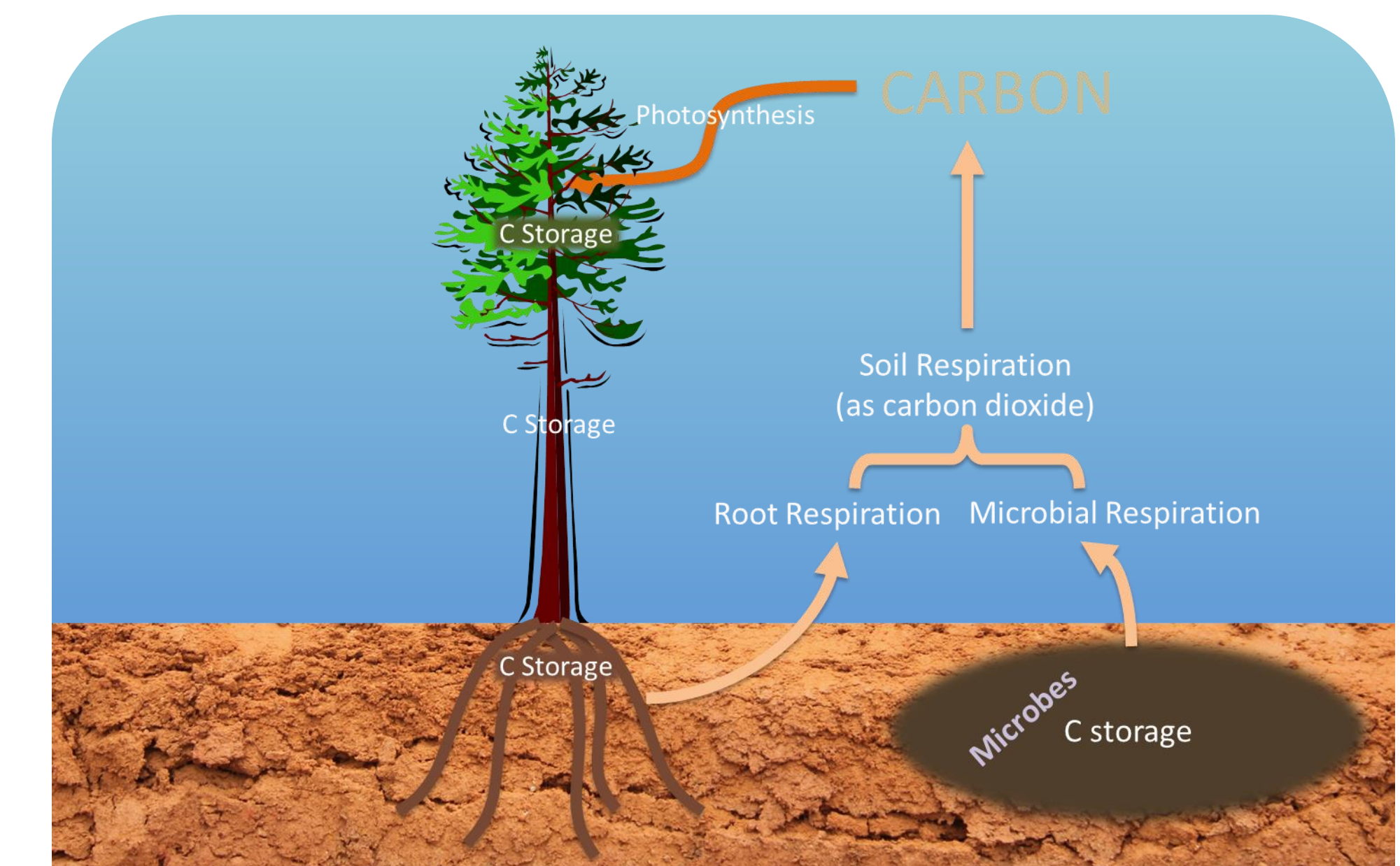


Figure 1: Simplified representation of carbon flux and storage in a pine plantation ecosystem. Root respiration is considered autotrophic and microbial respiration is considered heterotrophic.

Results

- R_s, T_s and VWC varied with date of measurement but were not significantly influenced by fertilization or throughfall exclusion (Figure 4).
- There were no significant interactive effects of measurement date, throughfall exclusion or fertilization on R_s, T_s or VWC (Table 1).
- However, measurement date had a significant effect on R_s, T_s and VWC (Table 1).
- The ranges of VWC for the control (C), fertilization (F), throughfall exclusion (R) and fertilization and throughfall exclusion (FR) treatments were 15.75 - 24.63, 13.38 - 23.32, 11.31 - 19.43, and 10.75 - 19.81%.
- The ranges of T_s for the C, F, R and FR treatments were 11.05 - 28.94, 10.11 - 27.94, 11.03 - 28.79, and 11.61 - 7.82 °C.
- The ranges of R_s for the C, F, R and FR treatments were 1.20 - 4.49, 0.93 - 3.36, 1.06 - 4.51, and 1.02 - 3.81 μmol CO₂ m⁻² s⁻¹.
- Future results will include the response of autotrophic and heterotrophic components of R_s to fertilization and throughfall exclusion treatments.

Source	Soil CO ₂ Efflux	Soil Temperature	Soil Moisture
Fertilization	0.1604	0.7813	0.7166
Throughfall Exclusion	0.5650	0.3043	0.1531
Fertilization × Throughfall Exclusion	0.3794	0.5623	0.8819
Date	<0.001	<0.001	<0.001
Date × Fertilization	0.5609	0.2574	0.9510
Date × Throughfall Exclusion	0.6974	0.9091	0.4100
Date × Fertilization × Throughfall Exclusion	0.5101	0.9523	0.4497

Table 1: Probability values for effects of fertilization, throughfall exclusion and fertilization with throughfall exclusion treatments, and sampling date on soil CO₂ efflux, soil temperature, and soil moisture.



Figure 2: Map of Washington, GA Tier III site treatments. Different blocks are represented by differently colored borders around plots.